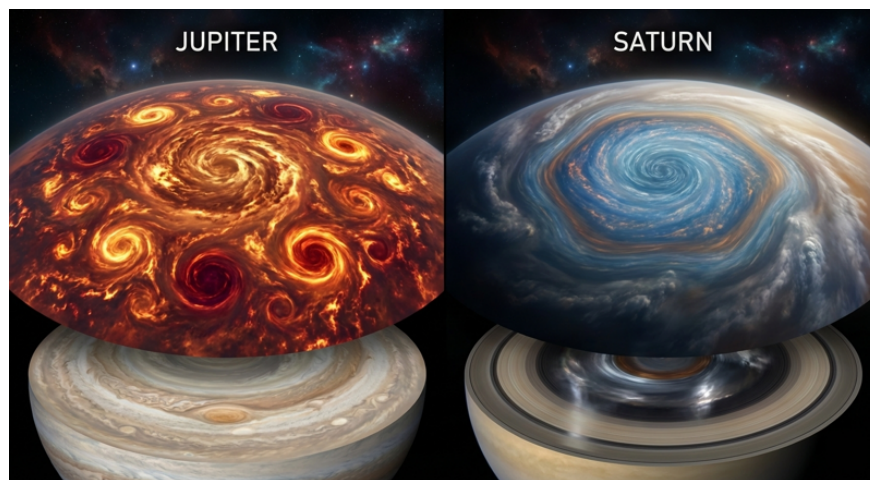


Polar cyclones reveal the hidden inner structures of Jupiter and Saturn.

The difference between Jupiter's and Saturn's polar vortices is due to the density of their cores: Saturn is harder and heavier than Jupiter, which is softer and lighter.

New research unravels the mysterious differences between two gas giant planets.

New research by planetary scientists at the Massachusetts Institute of Technology (MIT) suggests that the striking differences in **the polar cyclonic structure of Jupiter and Saturn** may stem from **characteristics deep within the planet's core** , offering crucial clues about **the internal structure of these gas giants** .



This composite image, constructed from data collected by **NASA's Juno probe JIRAM** , shows **a central vortex at Jupiter's North Pole** , surrounded by **eight smaller vortices** . JIRAM operates in the **infrared** range , and the colors in the image represent **radiant heat** :

1. Yellow clouds (thinner) have a light temperature of approximately **-13°C** .
2. While the deep red area (the densest cloud cover) can reach temperatures as low as **-83°C** .

Image source: NASA / JPL-Caltech / SwRI / ASI / INAF / JIRAM.

" Our research shows that the planet's internal properties and the 'softness' of the cyclone base directly influence the observed fluid flow patterns on the surface ," said Dr. Wanying Kang (MIT).

The research was inspired by detailed images of Jupiter and Saturn provided by NASA's **Juno** and **Cassini** missions .

Juno and Cassini: Two missions unlock the North Poles of gas planets.

The Juno spacecraft has been orbiting Jupiter since 2016 and has captured spectacular images of **the North Pole with its many intensely swirling cyclones** .

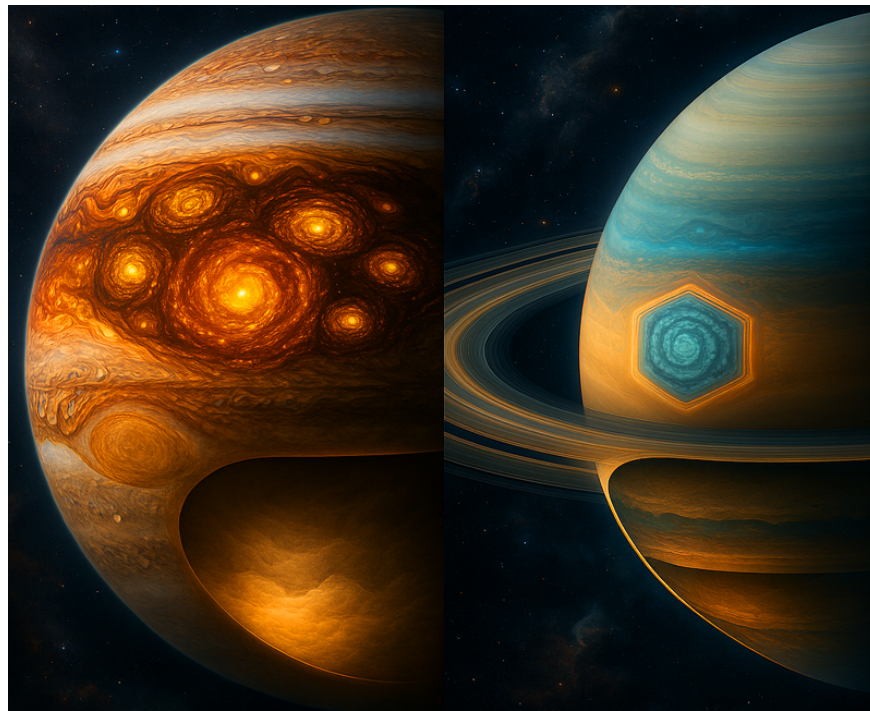
From this data, scientists estimate that each of Jupiter's cyclones has a diameter of up to **5,000 km** .

Meanwhile, the **Cassini** spacecraft – before self-destructing in Saturn's atmosphere in 2017 – orbited the planet for **13 years** .

Cassini discovered that at Saturn's North Pole there was only a single **hexagonal cyclone** , measuring up to **29,000 km** in diameter .

" **Jupiter and Saturn are almost identical in size and both are primarily composed of hydrogen and helium, but their polar cyclones are completely different** , and that has puzzled scientists for years," shared graduate student **Jiaru Shi** (MIT).

2D models help explain the phenomenon of polar vortices.



The research team aims to find **the physical mechanism** that explains why one planet forms **a single polar vortex** , while the other appears to have **many smaller vortices** .

They used a **two-dimensional (2D) fluid dynamics model** to simulate the evolution of cyclones on the planet's surface.

Although cyclones are essentially three-dimensional phenomena, due to **Jupiter and Saturn's extremely high rotation speeds**, fluid motion tends to be **uniform along the axis of rotation**, allowing the 3D problem to be reduced to 2D while maintaining accuracy.

" **In fast-rotating systems, fluid flow remains almost constant along the axis of rotation**, so a 2D model is perfectly reasonable," Dr. Kang explained.

"This makes simulations **hundreds of times faster** and significantly reduces computational costs."

The model is built upon an equation describing **the evolution of vortex flow**, which has been widely used to simulate **vortex storms at mid-latitudes on Earth**, and has been adapted to fit **the polar regions of gas planets**.

The 'softness' of the bottom of the whirlpool: the key to making the difference.



In the simulation scenarios, the research team varied several parameters, such as:

1. Planet size
2. Rotation speed
3. Internal heat source
4. And **the softness or stiffness of the air layer at the bottom of the vortex**.

Initially, the fluid is placed in a state of **random turbulence**, then allowed to evolve over time.

The results show that:

1. Some scenarios form a **giant vortex** , similar to Saturn.
2. While other scenarios create **multiple small vortices coexisting** , similar to Jupiter.

Further analysis reveals that **the determining factor lies in the softness of the material layer beneath the cyclone** :

1. If the gas layer at the bottom of the vortex **is light and soft** , the vortex cannot grow too large, allowing **many small vortices to coexist** at the planetary pole—as on Jupiter.
2. Conversely, if the bottom layer **is denser and more rigid** , the vortex can expand to planetary scale, forming a **single polar vortex** —as on Saturn.

If this mechanism is correct, it implies that **Jupiter has a lighter and softer internal structure** , while **Saturn may contain heavier, metal-rich, and condensed matter** , resulting in a more pronounced stratification.

" **What we observe on the surface can directly reflect the deep internal structure of the planet** ," Shi emphasized.

"This helps us better understand the true nature of these gas giant planets."

This research will be published in the prestigious scientific journal **Proceedings of the National Academy of Sciences (PNAS)** .

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